SUPERVISOR TO ATTACH
PROCESSING LABEL HERE

Write your **student number** in the boxes above. **Letter**

Systems Engineering

Question and Answer Book

VCE Examination – Monday 18 November 2024

- Reading time is **15 minutes**: 9.00 am to 9.15 am
- Writing time is **1 hour 30 minutes**: 9.15 am to 10.45 am

Approved materials

- One scientific calculator

Materials supplied

- Question and Answer Book of 28 pages
- Detachable Formula Sheet in the centrefold
- Multiple-Choice Answer Sheet

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.
- Detach the Formula Sheet from the centre of this book during reading time.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Contents

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

VICTORIA State Government

Section A – Multiple-choice questions

Instructions

- Answer **all** questions in pencil on your Multiple-Choice Answer Sheet.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

A golf cart accelerating at 5 m s^{-2} has a net force of 5000 N. What is the mass of the golf cart?

A. 100 kg

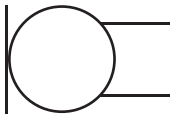
B. 250 kg

C. 1000 kg

D. 2500 kg

Question 2

The device shown in the diagram below is a



A. microphone.

B. resistor.

C. transistor.

D. light-emitting diode (LED).

Question 3

In a belt drive, if the number of input revolutions is 300 rpm and the number of output revolutions is 100 rpm, what is the pulley ratio?

A. 6.0

B. 5.0

C. 3.0

D. 1.5

Question 4

What is the power required to lift a load of 100 kg to a height of 2 m above the ground in 5 seconds? Assume that gravity = 10 m s^{-2}.

A. 400 W

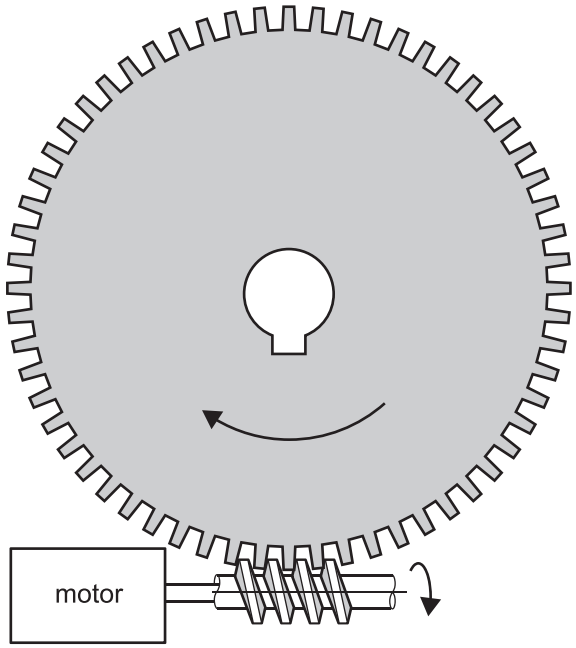
B. 2000 W

C. 10 000 W

D. 40 000 W

Question 5

In a single-start worm gear mechanism operated by a motor, if a wheel with 60 teeth turns one revolution in a minute, what is the rpm of the motor?



A. $\frac{1}{60}$

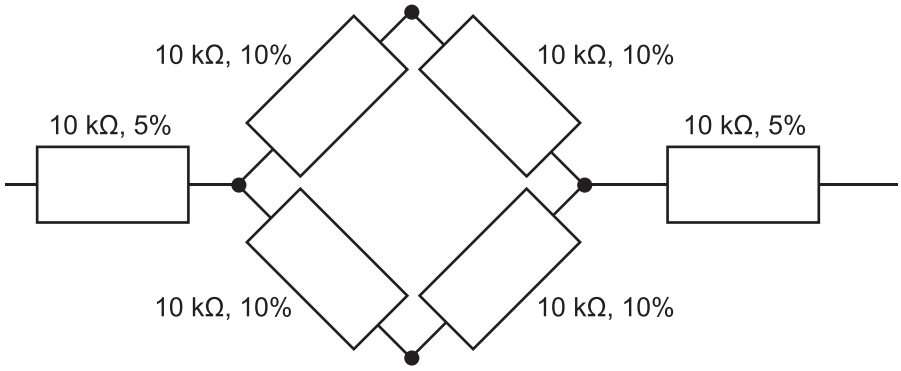
B. 1

C. 60

D. 3600

Question 6

The circuit below shows a network of six resistors, with nominal resistance and tolerances.



The maximum possible resistance of the circuit is

A. 28 kΩ

B. 32 kΩ

C. 60 kΩ

D. 63 kΩ

Question 7

A stepper motor, the shaft of which is connected to a compound gear system that has a mechanical advantage of 2, produces 200 steps per rotation.

What is the step size at the output of the compound gear system?

A. 0.9°

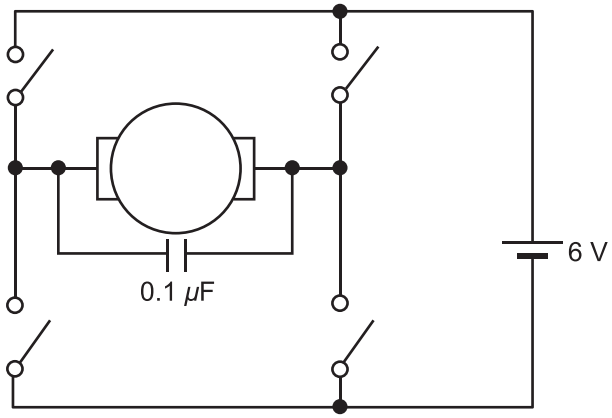
B. 1.8°

C. 2.0°

D. 3.6°

Question 8

A DC motor is connected to a circuit so that the motor's rotation can be reversed (shown in the circuit below). To reduce noise, a 0.1 μF capacitor is to be soldered across the terminals of the motor.



Which of the following capacitors is **not** suitable for this application?

A. 0.1 μF 35 V polarised capacitor

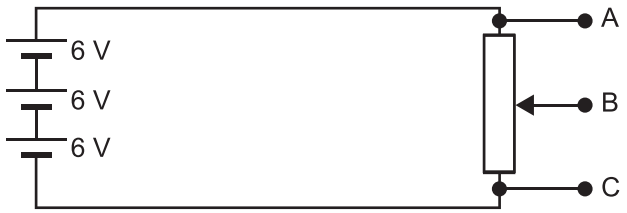
B. 0.1 μF 35 V non-polarised capacitor

C. 0.1 μF 100 V supercapacitor

D. 0.1 μF 35 V variable capacitor

Question 9

A variable resistor (potentiometer) is connected as shown below.



The potential difference measured across points B and C is 2 V. What is the voltage across points A and B?

A. 4 V

B. 6 V

C. 12 V

D. 16 V

Question 10

A brown-coal-fired power station is 30% efficient in converting the chemical energy in brown coal into electricity. From the electrical energy produced, 8% is used to run the power station itself. During transmission and distribution of the electrical energy, 10% is lost.

Compared to the chemical energy in the brown coal, the energy delivered to users is closest to

A. 12%

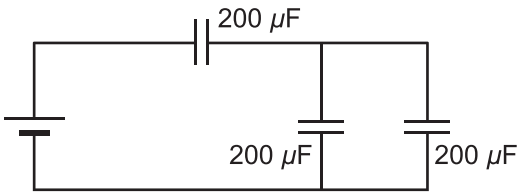
B. 25%

C. 48%

D. 70%

Question 11

The total capacitance of the following circuit is closest to



A. 67 μF

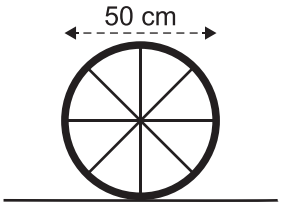
B. 133 μF

C. 300 μF

D. 600 μF

Question 12

The engine attached to the wheel in the image below is generating 480 N m of torque.



What is the force of the wheel on the road?

A. 120 N

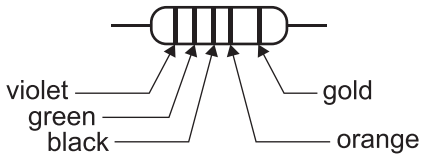
B. 240 N

C. 960 N

D. 1920 N

Question 13

Identify the value of the resistor pictured below.



A. 7503 Ω ± 5%

B. 7503 Ω ± 10%

C. 750 000 Ω ± 5%

D. 750 000 Ω ± 10%

Question 14

Which of the following devices is primarily an input transducer?

A. speaker

B. microphone

C. piezo buzzer

D. light-emitting diode (LED)

Question 15

Which of the following factors is important when addressing environmental sustainability during the creation of a system?

A. user preferences

B. cost-effectiveness

C. maximising profit margins

D. minimising waste and energy usage

Question 16

A force of 4400 N is applied to a circular piston 20 cm in diameter. What is the fluid pressure working against the piston?

A. 35 kPa

B. 110 kPa

C. 140 kPa

D. 440 kPa

Question 17

What is the difference between a ‘hazard’ and a ‘risk’?

A. Hazards are more severe than risks.

B. Risks are more severe than hazards.

C. The terms ‘hazard’ and ‘risk’ can be used interchangeably.

D. Hazards are potential sources of harm; risks are the likelihood that harm will occur.

Question 18

What type of control system uses feedback to adjust the output to maintain a constant set point?

A. manual control

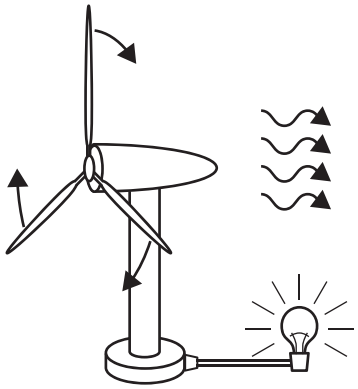
B. hydraulic system

C. open-loop system

D. closed-loop system

Question 19

Which of the changes below would **both** improve the wind turbine efficiency?



	Wind energy being harnessed to turn blades	Turbine converting kinetic energy into electrical energy
A.	Wind turbine placed in a location with higher wind energy.	A more efficient light bulb is plugged in.
B.	Wind turbine placed in a location with higher wind energy.	The generator is lubricated to reduce energy losses.
C.	Blades are curved to capture more of the wind's kinetic energy, transferring it to the wind turbine's kinetic energy.	A more efficient light bulb is plugged in.
D.	Blades are curved to capture more of the wind's kinetic energy, transferring it to the wind turbine's kinetic energy.	The generator is lubricated to reduce energy losses.

Question 20

If P_T is the power supplied by the turbine and P_{total} is the total power available from the wind, the efficiency of the wind turbine, η, is given by

A. $\eta = \frac{P_T}{P_{total}} \times 100$

B. $\eta = \frac{P_{total}}{P_T} \times 100$

C. $\eta = \frac{P_T - P_{total}}{P_{total}} \times 100$

D. $\eta = \frac{P_T}{P_T + P_{total}} \times 100$

End of Section A

Section B

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- All calculations must show appropriate formulas and working.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (3 marks)

Figure 1 below illustrates a variable resistor (potentiometer) and a 330 Ω resistor, wired in parallel.

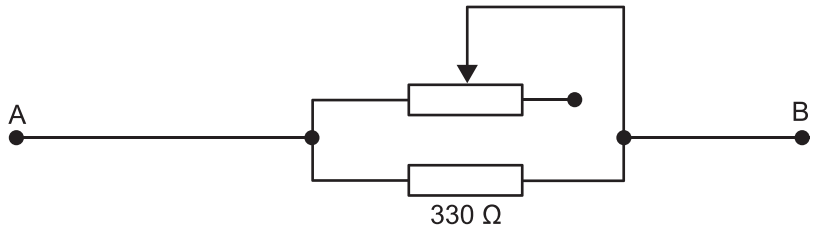


Figure 1

The graph in Figure 2 below was created after the parallel network shown in Figure 1 was tested for its voltage response to different current levels. During this testing the variable resistor (potentiometer) was not adjusted.

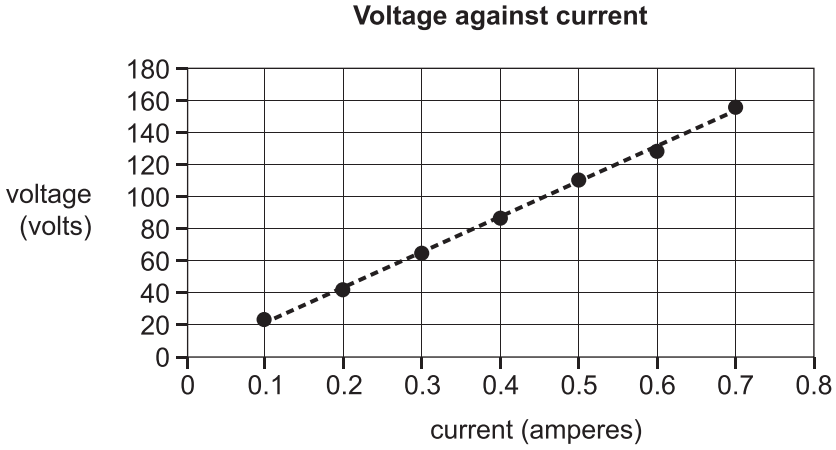


Figure 2

The relationship between the voltage (V) and current (I) was determined to be $V = 200 \times I$, based on the Figure 2 graph.

a. Determine the gradient of the graph. 1 mark

Do not write in this area.

b. Calculate the resistance of the part of the variable resistor (potentiometer) involved in the circuit. Show your working. 2 marks

Question 2 (4 marks)

The data sheet for a solar panel states that it has a peak output of 360 W when newly purchased.

a. How many panels will be required to produce 55 kW h of energy during a day with 14 hours of peak output? Show your working. 2 marks

b. The embodied energy of a product is the energy required to produce it. It is a one-off energy cost. The embodied energy for one of these solar panels is 585 kW h per m^2. The panel has an active surface area of 1.7 m^2.

Calculate the number of hours (to the nearest whole number) at peak output that will be required for a single panel to match its embodied energy. Show your working. 2 marks

Question 3 (5 marks)

Figure 3 shows a friction-free compound pulley system. Take the acceleration due to gravity as 10 m s^{-2}.

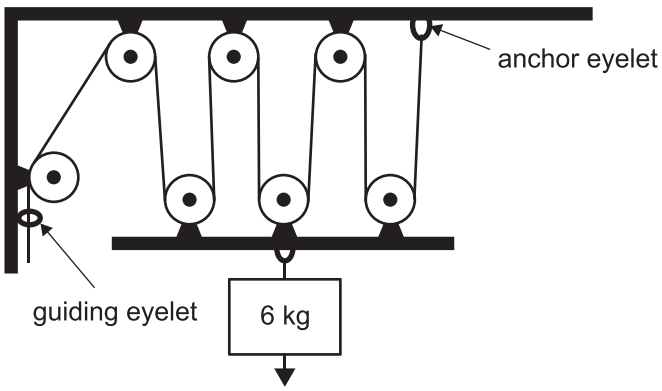


Figure 3

a. Calculate the work done on the load when it has been raised by 3 m. 2 marks

b. Calculate the amount of rope that must be pulled through the guiding eyelet to raise the load by 3 m. 1 mark

c. If the power applied at the input rope is 90 W, calculate the speed at which the input rope would pass through the guiding eyelet. 2 marks

Question 4 (6 marks)

The diagram in Figure 4 illustrates a machine that translates the motion of a crank to the motion of a lever.

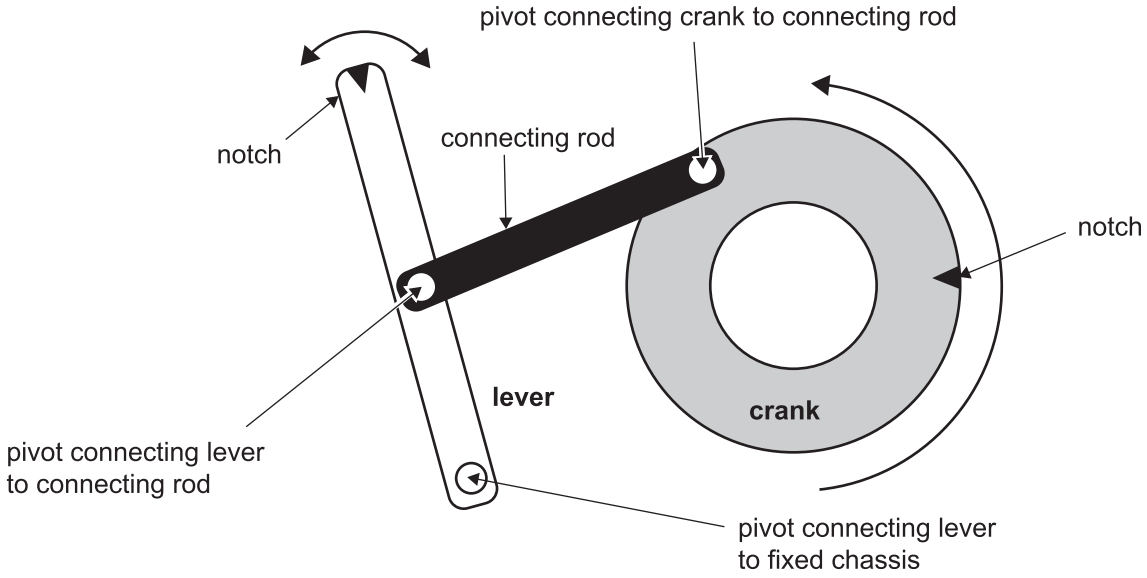


Figure 4

a. Describe a test procedure that uses a stopwatch and the notch inset into the crank to measure the rate of rotation of the crank. 3 marks

Question 4 continues on the next page.

b. Draw and describe a test procedure that uses a microswitch, a battery and a lamp to measure the rate of oscillation of the crank. 3 marks

Question 5 (4 marks)

A systems engineering student has designed an autonomous drone system. The drone is expected to deliver packages of up to 2 kg mass to the front doors of properties within a 1 km radius, without damaging the goods.

a. Outline **two** evaluation criteria for the mechanical and/or electronic aspects of the drone. 2 marks

b. Describe a testing method for the system to match the evaluation of **one** of the criteria outlined in **part a**. 2 marks

Question 6 (4 marks)

a. In the space provided below, design a compound gear mechanism of four gears (A, B, C, D) according to the specifications below, indicating the input and output gears clearly.

- A gear ratio of 3
- Direction of motion: Gear A clockwise, Gear C anticlockwise

3 marks

b. Calculate the output rotation speed, assuming an input rotation speed of 150 rpm. 1 mark

Question 7 (3 marks)

Mark wants to use a pulley mechanism to lift a load of 60 N by 2 m. If he needs to move the pulley rope by 5 m and apply an effort of 30 N to achieve this, what is the efficiency of the pulley? Show your working.

Question 8 (5 marks)

Figure 5 shows a lever system.

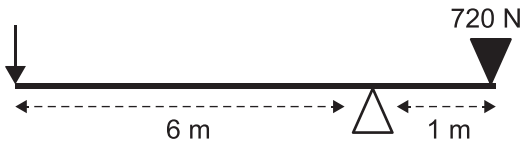


Figure 5

a. Identify the type of lever. Explain your answer. 2 marks

b. Calculate the minimum effort required to lift the load. Show your working. 2 marks

Question 8 continues on the next page.

c. Calculate the mechanical advantage of the lever system. 1 mark

Question 9 (10 marks)

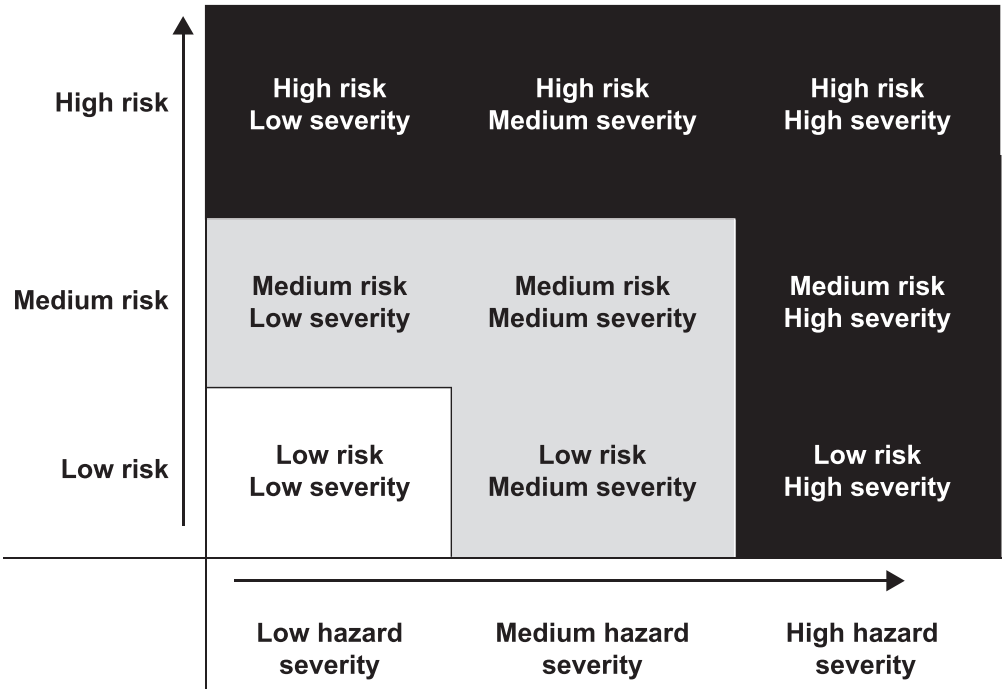
A new system for a potato chip factory that will open individual bags, allow chips to be poured in, and close the bags for sealing is to be built. A decision needs to be made between a hydraulic or pneumatic system for these purposes.

a. Describe hydraulic and pneumatic systems in terms of their similarities and differences. 4 marks

b. Identify which of the two systems would be most suitable for the potato chip packaging plant. Provide a reason for your answer. 2 marks

c. Table 1 shows the risk assessment matrix to predict the significance of hazards and take appropriate actions to deliver high-quality product.

Table 1 – Risk Assessment Matrix and Significance of Hazard



Key
■ High significance ▒ Medium significance □ Low significance

Table 2 shows part of the Potato Chip Hazard Analysis follow-up process table.

Fill in the blank spaces in Table 2 using the information provided in Table 1. The first row has been completed as an example. 4 marks

Table 2 – Potato Chip Hazard Analysis

Potential hazard	Risk	Hazard severity	Hazard level	Result
Metal fragment	Medium	High	Medium risk High severity	High hazard significance
Hair, part of packaging	Low	Medium	**(A)** _____	**(B)** _____
Ink	**(C)** _____	**(D)** _____	Low risk High severity	High hazard significance

Do not write in this area.

Question 10 (4 marks)

Figure 6 shows a circuit that a student has built in an attempt to convert AC electricity to DC electricity for their project.

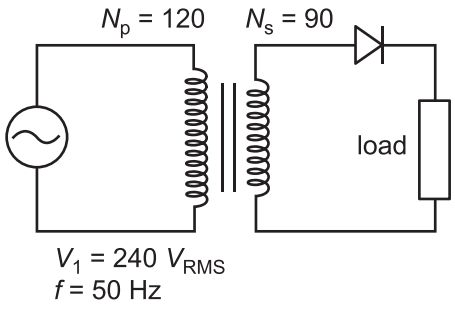
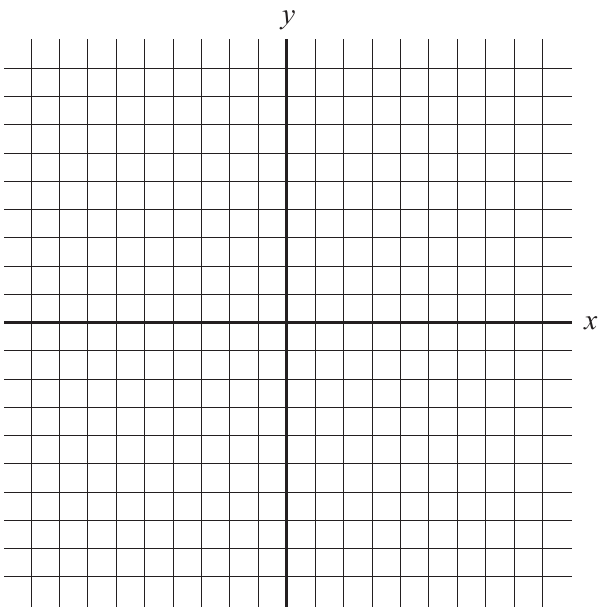


Figure 6

a. On the grid below, sketch the voltage signal you would expect to observe across the load in the secondary circuit when viewed on an oscilloscope. Ensure your drawing includes at least **two** complete cycles, clearly indicating the peak voltage and the period of the signal. 3 marks



b. Identify **one** improvement that could be made to make this circuit more effective as a DC circuit. 1 mark

Do not write in this area.

Question 11 (5 marks)

Figure 7 shows a circuit diagram and Figure 8 shows its PCB artwork.

Correctly connect the components together on the PCB artwork so that they match the circuit diagram.

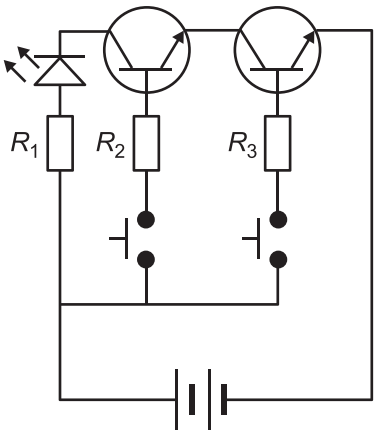


Figure 7

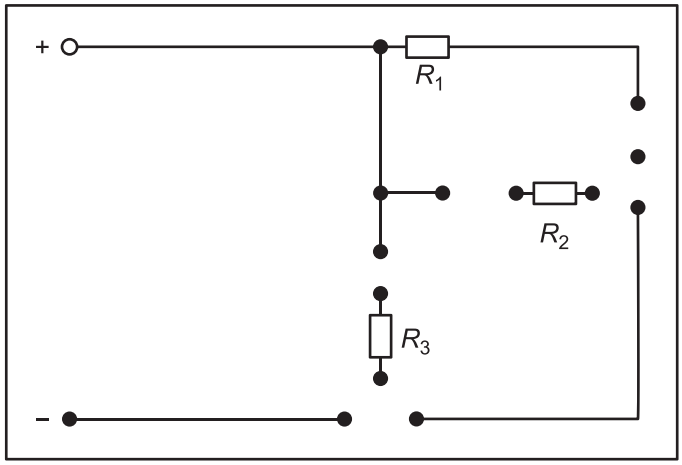


Figure 8

Question 12 (5 marks)

Industry 4.0 allows technology to inspect, model and visualise mass data, wirelessly fed through distributed electronic collectors, delivering real-time decision-making, enhanced productivity, flexibility and agility to revolutionise the healthcare industry.

Smart devices, such as watches, phones, and other devices that make use of wearable sensors, have attracted a lot of attention in the last decade, mostly in the healthcare field.

Source: Adapted from <ibm.com/topics/industry-4-0>

Analyse the potential of using smart devices in the healthcare industry. In your response, include a description of **one** possible application of a smart device, comment on **two** likely impacts of using it and address an issue that can be encountered using smart devices in the healthcare industry.

Question 13 (5 marks)

Figure 9 shows a simple circuit where an AC lamp is turned on by using a relay.

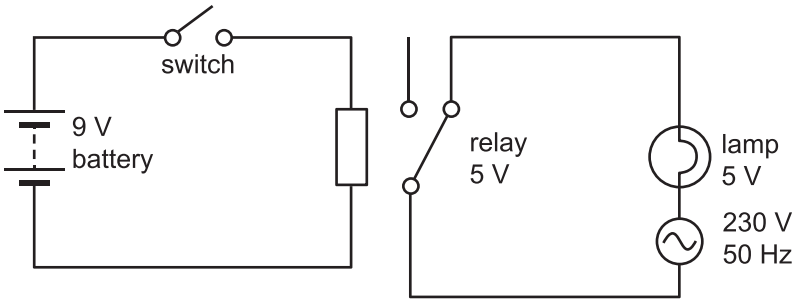


Figure 9

a. What is a relay? List **one** advantage of using a relay in the circuit. 2 marks

b. What is the purpose of the switch in the above circuit? 1 mark

c. Explain the working of the relay switch in Figure 9. 2 marks

Question 14 (7 marks)

When evaluating a temperature-and-light-sensor system to warn about cold conditions at night, it is important to evaluate the system to ensure that it sounds a warning signal when the temperature and the light intensity both fall below set levels.

The system contains the following components:

- an audible warning device
- a light-dependent resistor (LDR)
- a thermistor
- subsystem 1 – light detector
- subsystem 2 – temperature detector
- a microcontroller
- a transistor.

a. Complete the information in the block diagram in Figure 10 by writing the names of the missing components from the above list in the spaces provided below. 4 marks

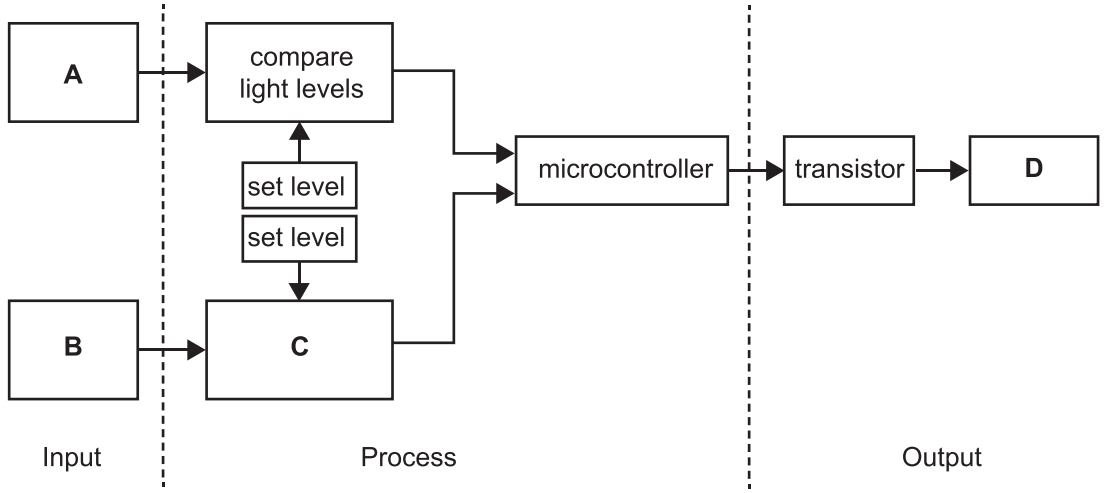


Figure 10

Source: Adapted from <https://reviseomatic.org/help/e-basics/Subsystems.ph>

A _____

B _____

C _____

D _____

Question 14 continues on the next page.

b. State the function of the two subsystems in the process section of the Input-Process-Output diagram, and the condition in which the microcontroller will trigger the alarm. 3 marks

Question 15 (5 marks)

Discuss the term ‘cradle-to-cradle analysis’ and how it could be applied to renewable energy sources. In your discussion, include **one** environmental, **one** economic, and **one** social benefit of using renewable energy sources.

Question 16 (5 marks)

Sam is looking for an off-grid system to power her shed. She opts for a 50 W PV (photovoltaic) standalone solar module as a power source and a common type of lead-acid battery (12 V, 7 A h) as a back-up system, as shown in Figure 11. This solar power diagram shows how a solar power system works.

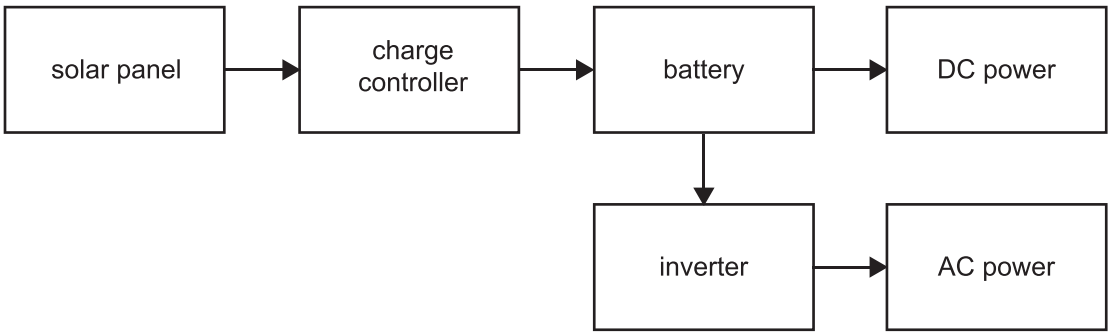


Figure 11

a. The tools Sam is going to use in her shed mainly operate on AC power.

Describe how the components of a solar power system work together to convert solar energy into electricity, including energy transformation, storage and use. 3 marks

b. Identify and describe **one** factor that affects the efficiency of energy conversion of a solar-powered system. 2 marks

End of examination questions

This page is blank.

This page is blank.

Systems Engineering

Formula Sheet

Please remove from the centre of this book during reading time.

You may keep this Formula Sheet.

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY
VICTORIA State Government

Mechanical

$\text{efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$	$\text{efficiency}_{\text{total}} = \text{efficiency}_1 \times \text{efficiency}_2$
$F = ma$	$\text{force due to gravity} = \text{mass} \times \text{acceleration due to gravity}$
$P = \dfrac{W}{t}$	$\text{work done} = \text{force in direction moved} \times \text{distance}$
$\text{torque} = \text{twisting force} \times \text{perpendicular distance to pivot point}$	$\text{moment} = \text{force} \times \text{perpendicular distance to pivot point}$
$F_1 d_1 = F_2 d_2$	$P = \dfrac{F}{A}$
$\text{speed} = \dfrac{\text{distance}}{\text{time}}$	$\text{mechanical advantage} = \dfrac{\text{load}}{\text{effort}}$
$\text{gear ratio final} = \text{gear ratio 1} \times \text{gear ratio 2}$	$\text{gear or pulley ratio} = \dfrac{\text{speed of driver (rpm)}}{\text{speed of driven (rpm)}}$
$\dfrac{\text{Gear A rpm}}{\text{Gear B rpm}} = \dfrac{\text{Gear B number of teeth}}{\text{Gear A number of teeth}}$	$\dfrac{\text{Pulley A rpm}}{\text{Pulley B rpm}} = \dfrac{\text{diameter of Pulley B}}{\text{diameter of Pulley A}}$
$\text{velocity ratio} = \dfrac{\text{distance moved by effort}}{\text{distance moved by load}}$	

Electrical

electrical energy efficiency $= \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$		$I = \frac{V}{R}$	
$P = VI$		$P = \frac{E}{t}$	
$f = \frac{1}{T}$		$V_x = \frac{R_x}{R_{total}} \times V_{supply}$	
$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$		$V_{peak} = \sqrt{2} V_{RMS}$	
resistors in series	$R_t = R_1 + R_2 + R_3 + \ldots$	resistors in parallel	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$
two resistors in parallel	$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$	capacitors in series	$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$
capacitors in parallel	$C_t = C_1 + C_2 + C_3 + \ldots$		

General

area of circle $= \pi r^2$ $(\pi = 3.14)$
circumference of circle $= 2\pi r$

Resistor colour codes

Colour	Value	Colour	Value	Colour	Tolerance
black	0	green	5	brown	1%
brown	1	blue	6	red	2%
red	2	violet	7	gold	5%
orange	3	grey	8	silver	10%
yellow	4	white	9		

End of Formula Sheet